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ABSTRACT

Causal modeling is examined for its heuristic value by describing its use in an introductory course in educational evaluation, and presenting a student-developed model. Subjects included students in either master's programs in statistics or doctoral programs in administration and curriculum. Before preparing an evaluation plan and path analysis, students were cautioned that: (1) development of causal models with observational data requires a close coordination of subject matter theory and the statistical model, large samples, and "checks and tests" against other types of evidence; and (2) the model should be kept simple and only variables amenable to change or intervention should be used. A causal model specifying variables expected to influence end-of-year achievement test scores in mathematics for grades 4-6 was designed. In the model, the school had adapted a new approach to mathematics, i.e. the "manipulative" approach. Variables that are amenable to intervention were used, and included parental and students' attitudes toward mathematics, and the degree of implementation of the manipulative approach. The specification of the model focuses on what the school can do to influence educational outcomes, rather than assuming that status characteristics will account for end-of-year performance.

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Educational Evaluation and Training:
The Heuristic Value of Causal Modeling

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The training of producers and consumers of educational evaluation occurs at federal, state and local (LEA) levels, and in a variety of settings, from Congress to LEA. As training is examined more analytically, there is a need to identify not only the substantive topics or content of evaluation training, but also the heuristics that can convey a sense of the conceptual foundations of evaluation as viewed from different perspectives. One such perspective is that of independent and dependent variables in an experimental or quasi-experimental settings. Another is the explanation of observational data. Path analysis or causal modeling can be used to assist students to clarify evaluation questions and the status of variables in a process or system view (Bentler, 1980). This paper examines causal modeling for its heuristic value by describing its use in a course setting, and presenting a student-developed model.

An heuristic services to guide, discover, or reveal, and this definition suggests the function of causal modeling for students in developing evaluation plans. The students who are developing evaluation plans are in an introductory course in educational evaluation. They include students who will be producers of evaluations--master's level students in research and evaluation who are

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trained in statistics, but the majority are doctoral students in administration and curriculum. These students are employed as principals, LEA directors of research and evaluation, curriculum coordinators, and comprise part of the future pool for superintendents and state-level administrators who will commission and read evaluation studies. Thus, the majority of the students do not have the statistics and research design background to conduct path analyses in an applied setting. What is possible, however, is to use the path analysis ideas as a framework to structure their conceptual understanding of their own area of expertise and their evaluation plans.

In the first two years of using path analysis, the topic was placed late in the course, following an introduction to experimental design issues and ways of documenting program implementation (which requires specification of program components). The end-of-course evaluation by students suggested that the topic be placed earlier in the course, so that will be tried in the coming year. Earlier placement will also permit the issue of specification as part of causal analysis to be more closely linked, also emphasizing the problems of specification error in causal explanations in observational studies (Cooley, 1978).² The evaluation by students also expressed their perceptions of the usefulness of the heuristic provided by path analysis.

²Specification error can occur, for example, when a variable that directly affects the dependent variable is not included. Cooley suggests that most evaluations of educational programs suffer from specification error, and identifies opportunity to learn as a factor that is not examined in program comparisons. Opportunity may be a function both of time allocated and overlap between the curricula and test (i.e., the knowledge and skills taught and measured). See also Cooley and Leinhardt, 1980.

Path Analysis. Bentler (1980) has provided a recent review "Multivariate Analysis with Latent Variables: Causal Modeling," in the Annual Review of Psychology. Basic concepts are defined, an overview of the field is provided (historical and scientific context, including a guide to the literature), and recent technical developments. Many social science research and regression texts also provide an introduction to path analysis (e.g., Lin, 1976; Kerlinger and Pedhazur, 1973).

As described by Bentler, a regression equation in the context of a causal model is called a structural equation and the parameters structural parameters. The representation of the regression equation is in a path diagram for the equation. A simple equation for a criterion, Y, and three predictor variables, X_1 , X_2 , and X_3 , is $Y = b_1X_1 + b_2X_2 + b_3X_3 + e$. The path diagram is shown in Figure 1 (a) and the complete model in (b).³ The predictors or independent variables are the X's; the criterion or dependent variable is Y. Causal or directional influences of the independent variables are shown by one direction arrows; the strength of each effect is given by the b weight for each arrow. Students are presented with the general concepts of regression, exogenous variables (those whose variability is assumed to be determined by causes outside the causal model), and endogenous variables (whose variability is explained by the exogenous or other endogenous variables in the system. Examples from the educational research literature are used (e.g., Cooley and Lohnes presentation of a path model for home environment and mathematics achievement, 1976, p. 158) to illustrate these concepts.

Background readings related to the topic have included Cooley and Lohnes (1976), reprints of articles by Wold and Duncan on causal modeling in The

³ Adapted from Bentler, 1980, p. 422.

evaluation of instruction: Issues and Problems (Wittrock and Wiley, 1970).

The Instructional Dimensions Study (Cooley and Leinhardt, 1980) will be added this year, as well as Cooley's (1978) general introduction to the topic for educational researchers. Students are cautioned that the development of causal models with observational data requires a close coordination of subject matter theory and the statistical model, large samples, and "checks and tests against other types of evidence (Ward, in Wittrock and Wiley, 1970). Students also examine the caveats put forward by Cook and Campbell (1979, pp. 301-309), and their emphasis on path analysis as a "tool for theoretical clarification."

As part of this introductory course, students prepare an evaluation plan. The programs identified for evaluation serve as the substantive areas for the class exercise on causal modeling. Students work in groups of three to four to design a path analysis for one of their evaluation plans. Students are advised to keep the model simple and to use only variables that are amenable to change or intervention. (That is, status variables such as IQ, Sex, and SES are not allowable in the model. These variables generally are "proxies" for psychological and educational variables that are theoretically related to achievement or attitude change. Bloom [1980] has drawn attention to this emphasis.)

A Student Model

Figure 2 shows a causal model specifying variables expected to influence end-of-year achievement test scores in mathematics for grades four through six. The school has adopted a new approach to mathematics in these grades, the "manipulative" approach. Key variables are the degree of implementation of the manipulative approach, and parental and students' attitudes toward

mathematics. The figure shows the paths to be tested, but the variables specified also reflect the orientation given to students. That orientation, as mentioned above, emphasizes the identification of variables that are amenable to intervention. In this case, parental attitudes, student attitudes, and degree of program implementation all are subject to further intervention.

The group of students who developed this representation, albeit a simple schema of the program complexity, speculated on the interventions that could be implemented if the manipulation of only one variable, the targeted manipulative approach, did not achieve the desired improvement in mathematics' scores. The specification of the model focuses attention on what the school can do, rather than assuming that status characteristics such as SES, Sex, "home environment," and so on, will account for end of year performance. Further identification of variables within the "degree of implementation" category would also focus student attention on the characteristics of the innovation that can be assessed and related to student achievement. Such characteristics may include, as suggested by the research of Cooley and Leinhardt (1980), each student's opportunity to learn each end-of-year test item (as assessed by the teacher) and by examining curricula and test overlap; the time the teacher interacts with individuals students, or with groups using the manipulative materials; individual student time spent with the materials "on task"; use of matching practices;⁴ and measures of sequence and pacing. Variables such as these have shown correlations with student gain in grade three mathematics. The effect of specifying individual variables in terms of classroom procedures and opportunity to learn, is to suggest to curriculum

⁴These include measures of frequency of testing, use of tests for assessing mastery, diagnosis or prescription, as well as percent correct on last test.

coordinators and administrators directions for in-service training and supervision. Even though these relationships may not be demonstrated through empirical data in LEAs, their specification assists the feedback-loop in evaluation.

Summary

In summary, students give high ratings to the use of causal modeling, yet causal modeling might be overlooked in initial courses in evaluation training because of the statistical training required to carry out such analyses.

Although most local evaluations do not meet criteria for causal modeling studies given by Wold, the heuristic requires students to examine the underlying assumptions and relationships of the variables that are likely to influence educational outcomes. The heuristic also facilitates linking the result of large scale studies, such as the Instructional Dimensions Study, to local evaluation planning. The course in which this approach to presenting causal modeling focuses on educational programs. The approach should also be useful in training evaluators of other social programs.

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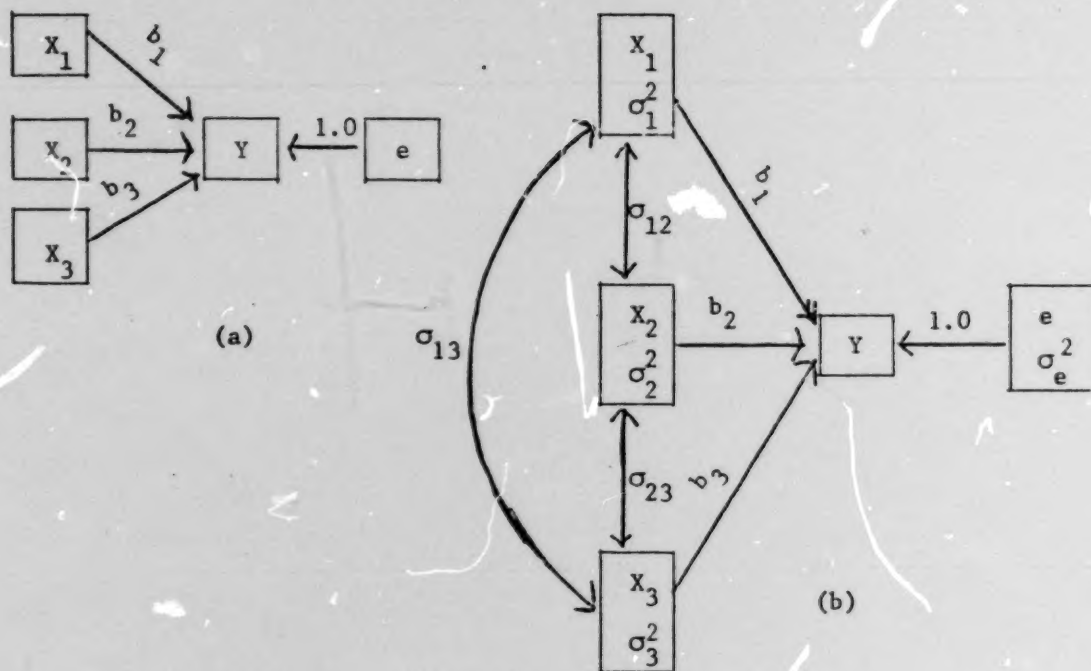


Figure 1. Sample Path Diagram

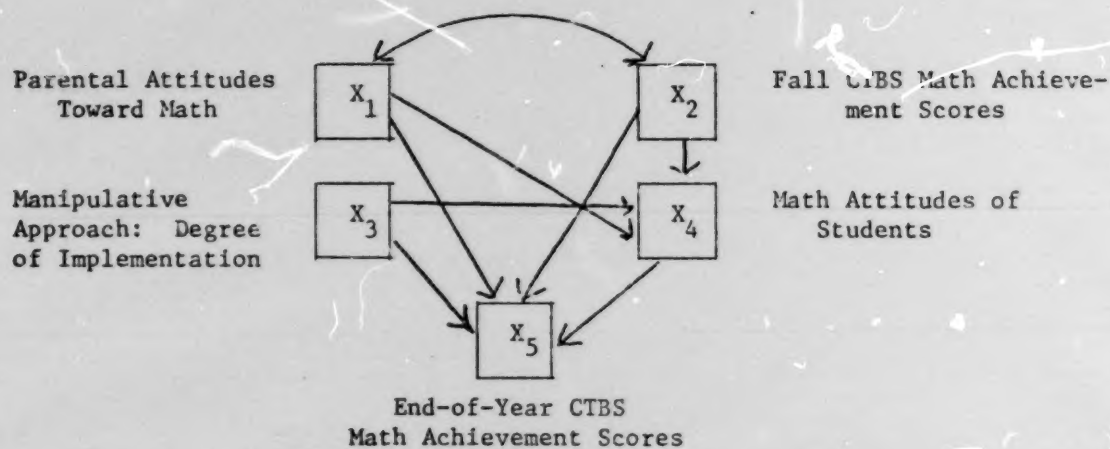


Figure 2. Path model showing expected influences on achievement test scores in mathematics.